BS ISO 80000-3:2007

Quantities and units —

Part 3: Space and time

ICS 01.060

British Standards

National foreword

This British Standard is the UK implementation of ISO 80000-3:2007. It supersedes BS ISO 31-1:1992 and BS ISO 31-2:1992, which are withdrawn.

The UK participation in its preparation was entrusted to Technical Committee SS/7, General metrology, quantities, units and symbols.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Part 3:
Space and time

Grandeurs et unités —

Partie 3: Espace et temps

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 80000-3 was prepared by Technical Committee ISO/TC 12, *Quantities, units, symbols, conversion factors*, in collaboration with IEC/TC 25, *Quantities and units, and their letter symbols*.

This first edition cancels and replaces the second edition of ISO 31-1:1992 and of ISO 31-2:1992. The major technical changes from the previous standards are the following:

— the presentation of *numerical statements* has been changed;

— the remark on logarithmic quantities and their units in the Introduction has been changed;

— the *normative references* have been changed;

— the quantities *radial distance, position vector, displacement* and *rotation* have been added to the list of quantities.

ISO 80000 consists of the following parts, under the general title *Quantities and units*:

— *Part 1: General*

— *Part 2: Mathematical signs and symbols for use in the natural sciences and technology*

— *Part 3: Space and time*

— *Part 4: Mechanics*

— *Part 5: Thermodynamics*

— *Part 7: Light*

— *Part 8: Acoustics*

— *Part 9: Physical chemistry and molecular physics*

— *Part 10: Atomic and nuclear physics*

— *Part 11: Characteristic numbers*

— *Part 12: Solid state physics*

IEC 80000 consists of the following parts, under the general title *Quantities and units*:

— *Part 6: Electromagnetism*

— *Part 13: Information science and technology*

— *Part 14: Telebiometrics related to human physiology*

Introduction

0.1 Arrangement of the tables

The tables of quantities and units in this International Standard are arranged so that the quantities are presented on the left-hand pages and the units on the corresponding right-hand pages.

All units between two full lines on the right-hand pages belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of an item has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parenthesis on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

0.2 Tables of quantities

The names in English and in French of the most important quantities within the field of this International Standard are given together with their symbols and, in most cases, their definitions. These names and symbols are recommendations. The definitions are given for identification of the quantities in the International System of Quantities (ISQ), listed on the left-hand pages of the table; they are not intended to be complete.

The scalar, vectorial or tensorial character of quantities is pointed out, especially when this is needed for the definitions.

In most cases only one name and only one symbol for the quantity are given; where two or more names or two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing. When two types of italic letters exist (for example as with ϑ and θ; φ and ϕ; *a* and a; *g* and g) only one of these is given. This does not mean that the other is not equally acceptable. It is not recommended to give such variants different meanings. A symbol within parenthesis implies that it is a reserve symbol, to be used when, in a particular context, the main symbol is in use with a different meaning.

In this English edition, the quantity names in French are printed in an italic font, and are preceded by *fr*. The gender of the French name is indicated by (m) for male and (f) for female, immediately after the noun in the French name.

0.3 Tables of units

0.3.1 General

The names of units for the corresponding quantities are given together with the international symbols and the definitions. These unit names are language-dependent, but the symbols are international and the same in all languages. For further information, see the SI Brochure (7^{th} edition 1998) from BIPM and ISO 80000-1[1)].

The units are arranged in the following way.

a) The coherent SI units are given first. The SI units have been adopted by the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures, CGPM). The use of coherent SI units

1) To be published.

is recommended; decimal multiples and submultiples formed with the SI prefixes are recommended even though not explicitly mentioned.

b) Some non-SI units are then given, being those accepted by the International Committee for Weights and Measures (Comité International des Poids et Mesures, CIPM), or by the International Organization of Legal Metrology (Organisation Internationale de Métrologie Légale, OIML), or by ISO and IEC, for use with the SI.

   Such units are separated from the SI units in the item by use of a broken line between the SI units and the other units.

c) Non-SI units currently accepted by the CIPM for use with the SI are given in small print (smaller than the text size) in the "Conversion factors and remarks" column.

d) Non-SI units that are not recommended are given only in annexes in some parts of this International Standard. These annexes are informative, in the first place for the conversion factors, and are not integral parts of the standard. These deprecated units are arranged in two groups:

   1) units in the CGS system with special names;

   2) units based on the foot, pound, second, and some other related units.

e) Other non-SI units given for information, especially regarding the conversion factors, are given in another informative annex.

0.3.2 Remark on units for quantities of dimension one, or dimensionless quantities

The coherent unit for any quantity of dimension one, also called a dimensionless quantity, is the number one, symbol 1. When the value of such a quantity is expressed, the unit symbol 1 is generally not written out explicitly.

EXAMPLE Refractive index $n = 1{,}53 \times 1 = 1{,}53$

Prefixes shall not be used to form multiples or submultiples of the unit one. Instead of prefixes, powers of 10 are recommended.

EXAMPLE Reynolds number $Re = 1{,}32 \times 10^3$

Considering that plane angle is generally expressed as the ratio of two lengths and solid angle as the ratio of two areas, in 1995 the CGPM specified that, in the SI, the radian, symbol rad, and steradian, symbol sr, are dimensionless derived units. This implies that the quantities plane angle and solid angle are considered as derived quantities of dimension one. The units radian and steradian are thus equal to one; they may either be omitted, or they may be used in expressions for derived units to facilitate distinction between quantities of different kind but having the same dimension.

0.4 Numerical statements in this International Standard

The sign $=$ is used to denote "is exactly equal to", the sign $\approx$ is used to denote "is approximately equal to", and the sign $:=$ is used to denote "is by definition equal to".

Numerical values of physical quantities that have been experimentally determined always have an associated measurement uncertainty. This uncertainty should always be specified. In this International Standard, the magnitude of the uncertainty is represented as in the following example.

EXAMPLE $l = 2{,}347\,82(32)$ m

In this example, $l = a(b)$ m, the numerical value of the uncertainty b indicated in parentheses is assumed to apply to the last (and least significant) digits of the numerical value a of the length l. This notation is used when b represents the standard uncertainty (estimated standard deviation) in the last digits of a. The numerical example given above may be interpreted to mean that the best estimate of the numerical value of the length l (when l is expressed in the unit metre) is 2,347 82, and that the unknown value of l is believed to lie between $(2{,}347\,82 - 0{,}000\,32)$ m and $(2{,}347\,82 + 0{,}000\,32)$ m, with a probability determined by the standard uncertainty 0,000 32 m and the probability distribution of the values of l.

0.5 Remark on logarithmic quantities and their units

The expression for the time dependence of a damped harmonic oscillation can be written either in real notation or as the real part of a complex notation

$$F(t) = A\mathrm{e}^{-\delta t}\cos\omega t = \mathrm{Re}(A\mathrm{e}^{(-\delta+\mathrm{i}\omega)t}), \quad A = F(0)$$

This simple relation involving δ and ω can be obtained only when e (base of natural logarithms) is used as the base of the exponential function. The coherent SI unit for the damping coefficient δ and the angular frequency ω is second to the power minus one, symbol s^{-1}. Using the special names neper, symbol Np, and radian, symbol rad, for the units of δt and ωt, respectively, the units for δ and ω become neper per second, symbol Np/s, and radian per second, symbol rad/s, respectively.

The corresponding variation in space is treated in the same manner

$$F(x) = A\mathrm{e}^{-\alpha x}\cos\beta x = \mathrm{Re}(A\mathrm{e}^{-\gamma x}), \quad A = F(0) \qquad \gamma = \alpha + \mathrm{i}\beta$$

where the unit for α is neper per metre, symbol Np/m, and the unit for β is radian per metre, symbol rad/m.

The taking of logarithms of complex quantities is usefully carried out only with the natural logarithm. In this International Standard, the level L_F of a field quantity F is therefore defined by convention as the natural logarithm of a ratio of the field quantity and a reference value F_0, $L_F = \ln(F/F_0)$, in accordance with decisions by CIPM and OIML. Since a field quantity is defined as a quantity whose square is proportional to power when it acts on a linear system, a square root is introduced in the expression of the level of a power quantity

$$L_P = \ln\sqrt{P/P_0} = (1/2)\ln(P/P_0)$$

when defined by convention using the natural logarithm, in order to make the level of the power quantity equal to the level of the corresponding field quantity when the proportionality factors are the same for the considered quantities and the reference quantities, respectively. See IEC 60027-3:2002, subclause 4.2.[2)]

The neper, symbol Np, and the bel, symbol B, are units for such logarithmic quantities.

The neper is the coherent unit when the logarithmic quantities are defined by convention using the natural logarithm, 1 Np = 1. The bel is the unit when the numerical value of the logarithmic quantity is expressed in terms of decimal logarithms, $1\ \mathrm{B} = (1/2)\ \ln 10\ \mathrm{Np} \approx 1{,}151\ 293\ \mathrm{Np}$. The use of the neper is mostly restricted to theoretical calculations on field quantities, when this unit is most convenient, whereas in other cases, especially for power quantities, the bel, or in practice its submultiple decibel, symbol dB, is widely used. It should be emphasized that the fact that the neper is chosen as the coherent unit does not imply that the use of the bel should be avoided. The bel is accepted by the CIPM and the OIML for use with the SI. This situation is in some respect similar to the fact that the unit degree (°) is commonly used in practice instead of the coherent SI unit radian (rad) for plane angle.

Generally it is not the logarithmic quantity itself, such as L_F or L_P, which is of interest; it is only the argument of the logarithm that is of interest, i.e. F/F_0 and P/P_0, respectively.

To avoid ambiguities in practical applications of logarithmic quantities, the unit should always be written out explicitly after the numerical value, even if the unit is neper, 1 Np = 1. Thus, for power quantities, the level is generally given by $L_P = 10\ \lg(P/P_0)$ dB, and it is the numerical value $10\ \lg(P/P_0)$ and the argument P/P_0 that are of interest. This numerical value is, however, not the same as the quantity L_P, because the unit decibel (or the unit bel) is not equal to one, 1. This applies to field quantities where the level is generally given by $L_F = 10\ \lg(F/F_0)^2$ dB.

2) IEC 60027-3:2002, *Letter symbols to be used in electrical technology — Part 3: Logarithmic and related quantities, and their units.*

EXAMPLE 1 The implication of the statement that $L_F = 3$ dB ($=$ 0,3 B) for the level of a field quantity is that it is to be read as meaning: $\lg(F/F_0)^2 = 0{,}3$, or $(F/F_0)^2 = 10^{0,3}$. (It also implies that $L_F \approx 0{,}3 \times 1{,}151\,293$ Np $= 0{,}345\,387\,9$ Np, but this is not often used in practice.)

EXAMPLE 2 Similarly, the implication of the statement that $L_P = 3$ dB ($=$ 0,3 B) for the level of a power quantity is that it is to be read as meaning: $\lg(P/P_0) = 0{,}3$, or $(P/P_0) = 10^{0,3}$. (It also implies that $L_P \approx 0{,}3 \times 1{,}151\,293$ Np $= 0{,}345\,387\,9$ Np, but this is not often used in practice.)

Meaningful measures of power quantities generally require time averaging to form a mean-square value that is proportional to power. Corresponding field quantities may then be obtained as the root-mean-square value. For such applications, the decimal (base 10) logarithm is generally used to form the level of field or power quantities. However, the natural logarithm could also be used for these applications, especially when the quantities are complex.

Quantities and units —

Part 3:
Space and time

1 Scope

ISO 80000-3 gives names, symbols and definitions for quantities and units of space and time. Where appropriate, conversion factors are also given.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8601:2004, *Data elements and interchange formats — Information interchange — Representation of dates and times*

3 Names, symbols and definitions

The names, symbols and definitions for quantities and units of space and time are given on the following pages.

SPACE AND TIME				QUANTITIES
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
3-1.1 (*1-3.1*)	length *fr longueur* (f)	l, L	length is one of the seven base quantities in the International System of Quantities, ISQ, on which the SI is based	Length is the quantity that can often be measured with a measuring rod.
3-1.2 (*1-3.2*)	breadth *fr largeur* (f)	b, B		
3-1.3 (*1-3.3*)	height *fr hauteur* (f)	h, H		The symbol H is often used to denote altitude, i.e. height above sea level, *fr altitude* (f).
3-1.4 (*1-3.4*)	thickness *fr épaisseur* (f)	d, δ		
3-1.5 (*1-3.5*)	radius *fr rayon* (m)	r, R		
3-1.6 (—)	radial distance *fr distance* (f) *radiale*	r_{Q}, ρ		Q is the notation of the axis from which the radial distance is determined.
3-1.7 (*1-3.6*)	diameter *fr diamètre* (m)	d, D		
3-1.8 (*1-3.7*)	length of path *fr longueur* (f) *curviligne*	s		
3-1.9 (*1-3.8*)	distance *fr distance* (f)	d, r		
3-1.10 (*1-3.9*)	cartesian coordinates *fr coordonnées* (f) *cartésiennes*	x, y, z		
3-1.11 (—)	position vector *fr rayon* (m) *vecteur*	$\boldsymbol{r}$		
3-1.12 (—)	displacement *fr déplacement* (m)	$\Delta\boldsymbol{r}$		
3-1.13 (*1-3.10*)	radius of curvature *fr rayon* (m) *de courbure*	ρ		

UNITS				SPACE AND TIME
Item No.	**Name**	**International symbol**	**Definition**	**Conversion factors and remarks**
3-1.a	metre	m	length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second. [17th CGPM (1983)]	This definition implies that the speed of light in vacuum (item 6-34.2) is exactly 299 792 458 m/s. In the English definition of the metre, the phrase “time interval” is used as a synonym for “duration” (item 3-7). The use of “time interval” for “duration” should, however, be avoided. ångström (Å), 1 Å := 10^{-10} m nautical mile, 1 nautical mile := 1 852 m

(*continued*)

SPACE AND TIME				QUANTITIES
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
3-2 (*1-4*)	curvature *fr courbure* (f)	$\varkappa$	$\varkappa = 1/\rho$ where ρ is radius of curvature (item 3-1.13)	
3-3 (*1-5*)	area *fr aire* (f), *superficie* (f)	A, (S)	$A = \iint \mathrm{d}x\, \mathrm{d}y$ where x and y are cartesian coordinates (item 3-1.10)	The vector surface element of area $\mathrm{d}A$ is written $\boldsymbol{e}_\mathrm{n}\, \mathrm{d}A$, where $\boldsymbol{e}_\mathrm{n}$ is a unit vector perpendicular to the surface. $A = \int \mathrm{d}A$ For a scalar surface element of area $\mathrm{d}A$, $\mathrm{d}\sigma$ is sometimes also used.
3-4 (*1-6*)	volume *fr volume* (m)	V	$V = \iiint \mathrm{d}x\, \mathrm{d}y\, \mathrm{d}z$ where x, y and z are cartesian coordinates (item 3-1.10)	$V = \int \mathrm{d}V$ For a volume element $\mathrm{d}V$, $\mathrm{d}\tau$ is sometimes also used.
3-5 (*1-1*)	angle, plane angle *fr angle* (m), *angle* (m) *plan*	α, β, γ, ϑ, φ	$\alpha = s/r$ where s is the length of the included arc of a circle between two radii of the circle (item 3-1.8) and r is the radius of the circle (item 3-1.5)	Other symbols are also used. See also rotation (item 3-14).

UNITS				SPACE AND TIME
Item No.	**Name**	**International symbol**	**Definition**	**Conversion factors and remarks**
3-2.a	metre to the power minus one	m^{-1}		
3-3.a	square metre	m^2		are (a), $1\ a := 100\ m^2$ The unit are, and its multiple hectare (ha) are used to express land areas.
3-4.a	cubic metre	m^3		
3-4.b	litre	l, L	$1\ l := 10^{-3}\ m^3 = 1\ dm^3$	As an exception, in 1979 the CGPM adopted the capital L as a second symbol for the unit litre, although it is not derived from a proper name. Therefore, in International Standards only the symbol lower case l is used.
3-5.a	radian	rad	$1\ rad := 1\ m/m = 1$	See the Introduction, 0.3.2. The radian is the angle between two radii of a circle that cuts off on the circumference an arc equal in length to the radius of the circle.
3-5.b	degree, (degree of arc)	$^\circ$	$1^\circ := (\pi/180)\ rad$	$1^\circ \approx 0{,}017\ 453\ 3\ rad$ There shall be no space between a numerical value and any of the three superscript-type unit symbols 3-5.b, c, d. The degree should preferably be subdivided decimally rather than using the minute or second. The unit symbol shall then be placed after the last decimal in the numerical value.
3-5.c	minute, (minute of arc)	$'$	$1' := (1/60)^\circ$	
3-5.d	second (second of arc)	$''$	$1'' := (1/60)'$	EXAMPLE Write $17{,}25^\circ$ rather than $17^\circ 15'$.
3-5.e	gon	gon	$1\ gon := (\pi/200)\ rad$	In navigation, however, the minute is still used.

(*continued*)

SPACE AND TIME				QUANTITIES
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
3-6 (*1-2*)	solid angle *fr angle* (m) *solide*	$\varOmega$	$\varOmega = A/r^2$ where A is the area of the included surface of a sphere in a cone with its apex at the centre of the sphere (item 3-3) and r is the radius of the sphere (item 3-1.5)	
3-7 (*1-7*)	time, duration *fr durée* (f), *temps* (m)	t	time is one of the seven base quantities in the International System of Quantities, ISQ, on which the SI is based	Time is the quantity that can often be measured with a chronometer.
3-8.1 (*1-10*)	velocity, speed *fr vitesse* (f)	$\boldsymbol{v}$, u, v, w	$\boldsymbol{v} = \mathrm{d}\boldsymbol{r}/\mathrm{d}t$ where $\boldsymbol{r}$ is position vector (item 3-1.11) and t is time (item 3-7)	When the general symbol $\boldsymbol{v}$ is not used for the velocity, u, v, w may be used for the components of the velocity. In the English language the magnitude of the velocity, $v = \lvert\boldsymbol{v}\rvert$, is usually called speed.
3-8.2 (*1-10*)	speed of propagation of waves *fr vitesse* (f) *de propagation d'ondes*	c		c is used for speed of propagation of waves to distinguish it from other kinds of speed.

UNITS				SPACE AND TIME
Item No.	**Name**	**International symbol**	**Definition**	**Conversion factors and remarks**
3-6.a	steradian	sr	$1\ \text{sr} := 1\ \text{m}^2/\text{m}^2 = 1$	See the Introduction, 0.3.2. The steradian is the solid angle of a cone that, having its apex in the centre of a sphere, cuts off on the sphere a surface equal in area to a square with sides of length equal to the radius of the sphere.
3-7.a	second	s	duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom [13th CGPM (1967)]	For the representation of dates and time of the day, see ISO 8601. According to ISO 8601, dates and times are stated as in the following example: year-month-day: 1935-12-04 hour-minute-second: 09:30:35
3-7.b	minute	min	$1\ \text{min} := 60\ \text{s}$	
3-7.c	hour	h	$1\ \text{h} := 60\ \text{min} = 3\,600\ \text{s}$	
3-7.d	day	d	$1\ \text{d} := 24\ \text{h} = 86\,400\ \text{s}$	
3-8.a	metre per second	m/s		
3-8.b	kilometre per hour	km/h		$1\ \text{km/h} = (1/3{,}6)\ \text{m/s} \approx 0{,}277\,778\ \text{m/s}$ knot (kn), $1\ \text{kn} :=$ 1 nautical mile per hour = $(1\,852/3\,600)\ \text{m/s} \approx 0{,}514\,444\ \text{m/s}$

(*continued*)

SPACE AND TIME				QUANTITIES
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
3-9.1 (*1-11.1*)	acceleration *fr accélération* (f)	$\boldsymbol{a}$	$\boldsymbol{a} = \mathrm{d}\boldsymbol{v}/\mathrm{d}t$ where $\boldsymbol{v}$ is velocity (item 3-8.1) and t is time (item 3-7)	
3-9.2 (*3-11.2*)	acceleration of free fall *fr accélération* (f) *due à la pesanteur* *accélération* (f) *en chute libre*	$\boldsymbol{g}$		Standard acceleration of free fall: $g_\mathrm{n} := 9{,}806\ 65\ \mathrm{m/s^2}$ In English this quantity, g_n, was earlier also called “standard acceleration due to gravity”. See 3rd CGPM (1901).
3-10 (*1-8*)	angular velocity *fr vitesse* (f) *angulaire*	$\boldsymbol{\omega}$, ω	$\omega = \mathrm{d}\varphi/\mathrm{d}t$ where φ is plane angle (item 3-5) and t is time (item 3-7)	The vector $\boldsymbol{\omega}$ is directed along the axis of rotation in the direction for which the rotation is clockwise. See also rotational frequency (item 3-15.2).
3-11 (*1-9*)	angular acceleration *fr accélération* (f) *angulaire*	$\boldsymbol{\alpha}$	$\boldsymbol{\alpha} = \mathrm{d}\boldsymbol{\omega}/\mathrm{d}t$ where $\boldsymbol{\omega}$ is angular velocity (item 3-10) and t is time (item 3-7)	
3-12 (*2-1*)	period duration, period *fr période* (f)	T	duration of one cycle	
3-13 (*2-2*)	time constant *fr constante* (f) *de temps*	τ, (T)	if a quantity is a function of time given by $F(t) = A + B\mathrm{e}^{-t/\tau}$ where t is time (item 3-7) and A and B are two constants, then τ is the time constant	Here time constant applies to an exponentially varying quantity. There are other time constants.
3-14 (—)	rotation *fr rotation* (f)	N	$N = \varphi/2\pi$ where φ is plane angle (item 3-5)	N is equal to the number (not necessarily integer) of turns, e.g. of a rotating body or in a coil.
3-15.1 (*2-3.1*)	frequency *fr fréquence* (f)	f, ν	$f = 1/T$ where T is period (item 3-12)	
3-15.2 (*2-3.2*)	rotational frequency *fr fréquence* (f) *de rotation*	n	$n = \mathrm{d}N/\mathrm{d}t$ where N is rotation (item 3-14) and t is time (item 3-7)	$n = \omega/2\pi$, where ω is angular velocity (item 3-10).

UNITS				SPACE AND TIME
Item No.	**Name**	**Inter-national symbol**	**Definition**	**Conversion factors and remarks**
3-9.a	metre per second squared	m/s^2		
3-10.a	radian per second	rad/s		For units other than radian, see 3-5.b, c, d, e.
3-11.a	radian per second squared	rad/s^2		For units other than radian, see 3-5.b, c, d, e.
3-12.a	second	s		
3-13.a	second	s		
3-14.a	one	1		See the Introduction, 0.3.2. The special name revolution, symbol r, for this unit is widely used in specifications on rotating machines.
3-15.a	hertz	Hz	$1\ \mathrm{Hz} := 1\ \mathrm{s}^{-1}$	
3-15.b	second to the power minus one	s^{-1}		The units revolution per second, symbol r/s, and revolution per minute, symbol r/min, are widely used in specifications for rotating machines (see also item 3-14.a).

(*continued*)

SPACE AND TIME				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
3-16 (*2-4*)	angular frequency *fr pulsation* (f), *fréquence* (f) *angulaire*	ω	$\omega = 2\pi f$ where f is frequency (item 3-15.1)	
3-17 (*2-5*)	wavelength *fr longueur* (f) *d'onde*	λ	distance in the direction of propagation of a sinusoidal wave between two successive points where at a given instant in time the phase differs by 2π (see remark to item 3-25)	
3-18 (*2-6*)	wavenumber, repetency *fr nombre* (m) *d'onde* (*linéique*), *répétence* (f) (*linéique*)	σ, $\widetilde{\nu}$	$\sigma = 1/\lambda$ where λ is wavelength (item 3-17)	The vector $\boldsymbol{k}$, corresponding to item 3-19, is generally called the wave vector. Also the vector $\boldsymbol{\sigma}$ is sometimes called the wave vector. In English, the names repetency and angular repetency should be used instead of wavenumber and angular wavenumber, respectively, since these quantities are not numbers.
3-19 (*2-7*)	angular wavenumber, angular repetency *fr nombre* (m) *d'onde* *angulaire*, *répétence* (f) *angulaire*	k	$k = 2\pi\sigma$ where σ is wavenumber (item 3-18)	
3-20.1 (*2-8.1*)	phase velocity, phase speed *fr vitesse* (f) *de* *phase*	c, v c_φ, v_φ	$c = \dfrac{\omega}{k}$ where ω is angular frequency (item 3-16) and k is angular wavenumber (item 3-19)	If speeds of electromagnetic waves and other speeds are both involved, then c should be used for the former and v for the latter. Phase speed may also be written $c = \lambda f$.
3-20.2 (*2-8.2*)	group velocity, group speed *fr vitesse* (f) *de* *groupe*	c_g, v_g	$c_\mathrm{g} = \dfrac{\mathrm{d}\omega}{\mathrm{d}k}$ where ω is angular frequency (item 3-16) and k is angular wavenumber (item 3-19)	

UNITS				SPACE AND TIME
Item No.	**Name**	**International symbol**	**Definition**	**Conversion factors and remarks**
3-16.a 3-16.b	radian per second second to the power minus one	rad/s s^{-1}		See the Introduction, 0.3.2.
3-17.a	metre	m		ångström (Å), 1 Å := 10^{-10} m
3-18.a	metre to the power minus one	m^{-1}		In spectroscopy, the multiple cm^{-1} is generally used.
3-19.a 3-19.b	radian per metre metre to the power minus one	rad/m m^{-1}		See the Introduction, 0.3.2.
3-20.a	metre per second	m/s		

(*continued*)

SPACE AND TIME				QUANTITIES
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
3-21 (*2-9*)	level of a field quantity *fr niveau* (m) *d'une grandeur de champ*	L_F	$L_F = \ln \dfrac{F}{F_0}$ where F and F_0 represent two field quantities of the same kind, F_0 being a reference quantity In most practical applications this definition is written $L_F = 20 \lg \left(\dfrac{F}{F_0}\right) \text{ dB} = 10 \lg \left(\dfrac{F}{F_0}\right)^2 \text{ dB}$	If $P/P_0 = (F/F_0)^2$, then $L_F = L_P$. Similar names, symbols and definitions apply to specific field quantities or power quantities, respectively (see the Introduction, 0.5). The quantity on which the level is based should be specified in the name and by the subscript of the symbol, e.g. level of electric field strength L_E. The difference between two levels of field quantities with the same reference F_0 is called the level difference of field quantities $\Delta L_F = \ln \dfrac{F_1}{F_0} - \ln \dfrac{F_2}{F_0} = \ln \dfrac{F_1}{F_2}$ independent of F_0. The same applies to power quantities.
3-22 (*2-10*)	level of a power quantity *fr niveau* (m) *d'une grandeur de puissance*	L_P	$L_P = \dfrac{1}{2} \ln \dfrac{P}{P_0} = \ln \sqrt{\dfrac{P}{P_0}}$ where P and P_0 represent two power quantities of the same kind, P_0 being a reference quantity In most practical applications, this definition is written $L_P = 10 \lg \dfrac{P}{P_0} \text{ dB}$	
3-23 (*2-11*)	damping coefficient *fr coefficient* (m) *d'amortissement*	δ	$\delta = 1/\tau$ where τ is the time constant of an exponentially varying quantity (item 3-13)	If a quantity is a function of time given by $F(t) = A\mathrm{e}^{-\delta t} \cos[\omega(t - t_0)]$ then δ is the damping coefficient. The quantity $\omega(t - t_0)$ is called the phase.
3-24 (*2-12*)	logarithmic decrement *fr décrément* (m) *logarithmique*	Λ	$\Lambda = \delta T$ where δ is damping coefficient (item 3-23) and T is period (item 3-12)	

UNITS				SPACE AND TIME
Item No.	**Name**	**International symbol**	**Definition**	**Conversion factors and remarks**
3-21.a	neper	Np	$1\ \text{Np} := \ln \text{e} = 1$	See the Introduction, 0.5. 1 Np is the level of a field quantity when $\ln(F/F_0) = 1$; i.e. $F/F_0 = \text{e}$. The decibel, dB, is the most commonly used unit. $1\ \text{dB} = \frac{1}{10} \ln\sqrt{10}\ \text{Np} \approx$ 0,115 129 3 Np $L_F = \ln \frac{F}{F_0}\ \text{Np} = 10 \lg \left(\frac{F}{F_0}\right)^2\ \text{dB}$
3-21.b	bel	B	$1\ \text{B} = \ln \sqrt{10}\ \text{Np}$	
3-22.a	neper	Np	$1\ \text{Np} := \ln \text{e} = 1$	See the Introduction, 0.5. 1 Np is the level of a power quantity when $\ln \sqrt{\frac{P}{P_0}} = 1$; i.e. $P/P_0 = \text{e}^2$. The decibel, dB, is the most commonly used unit. $1\ \text{dB} = \frac{1}{10} \ln\sqrt{10}\ \text{Np} \approx$ 0,115 129 3 Np $L_P = \ln \sqrt{\frac{P}{P_0}}\ \text{Np} = 10 \lg \frac{P}{P_0}\ \text{dB}$
3-22.b	bel	B	$1\ \text{B} = \ln \sqrt{10}\ \text{Np}$	
3-23.a	second to the power minus one	s^{-1}		
3.23.b	neper per second	Np/s		See the Introduction, 0.5. Damping coefficient is also expressed with the unit decibel per second, symbol dB/s.
3-24.a	one	1		See the Introduction, 0.3.2.
3-24.b	neper	Np		See the Introduction, 0.5. Logarithmic decrement is also expressed with the unit decibel, symbol dB.

(*continued*)

SPACE AND TIME				QUANTITIES
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
3-25.1 (*2-13-1*)	attenuation coefficient *fr affaiblissement* (m) *linéique*	α	If a quantity F is a function of distance x given by $F(x) = A\mathrm{e}^{-\alpha x}\cos[\beta(x - x_0)]$ then α is attenuation coefficient and β is phase coefficient	The quantity $1/\alpha$ is called the attenuation length. The quantity $\beta(x - x_0)$ is called the phase.
3-25.2 (*2-13.2*)	phase coefficient *fr déphasage* (m) *linéique*	β		
3-25.3 (*2-13-3*)	propagation coefficient *fr exposant* (m) *linéique de propagation*	γ	$\gamma = \alpha + \mathrm{i}\beta$	$-\mathrm{i}\gamma$ is the complex angular wavenumber.

UNITS				SPACE AND TIME
Item No.	**Name**	**International symbol**	**Definition**	**Conversion factors and remarks**
3-25.a	metre to the power minus one	m^{-1}		See the Introduction, 0.5. α and β are often given in neper per metre and radian per metre, respectively. α is also expressed in the unit decibel per metre, symbol dB/m.

(*concluded*)

Annex A
(informative)

Units in the CGS system with special names

The use of these units is deprecated.

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Conversion factors and remarks
3-9.1	acceleration	3-9.A.a	gal: Gal	1 Gal := 1 cm/s^2 = 0,01 m/s^2 The milligal (mGal) is commonly used in geodesy.

Annex B
(informative)

Units based on the foot, pound, second, and some other related units

The use of these units is deprecated

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Conversion factors and remarks
3-1	length	3-1.B.a	inch: in	1 in := 25,4 mm This definition was adopted legally by the United States in 1959 (Announcement US Dept. of Commerce, National Bureau of Standards, F.R. Doc. 59-5442 d.d. June 30, 1959) and by the United Kingdom in 1963 (Weights and Measures Act, 1963). The “mil” or “thou” is sometimes used to denote the “milli-inch”.
		3-1.B.b	foot: ft	1 ft := 12 in = 0,304 8 m The US Survey foot is defined as 1 US Survey foot equal to $\frac{1\,200}{3\,937}$ m $= (0{,}304\,8\ \mathrm{m})/0{,}999\,998 \approx 0{,}304\,800\,6$ m
		3-1.B.c	yard: yd	1 yd := 3 ft = 36 in = 0,914 4 m
		3-1.B.d	mile: mi	1 mi := 1 760 yd = 5 280 ft = 1 609,344 m The mile of 5 280 ft is also known as the statute mile. 1 US Survey mile := 5 280 US Survey foot ≈ 1 609,347 m
3-3	area	3-3.B.a	square inch: in^2	1 in^2 = 645,16 mm^2 The “circular mil” is sometimes used to designate an area of $(\pi/4) \times 10^{-6}\ \mathrm{in}^2 \approx 506{,}707\ \mu\mathrm{m}^2$
		3-3.B.b	square foot: ft^2	1 ft^2 = 0,092 903 04 m^2
		3-3.B.c	square yard: yd^2	1 yd^2 = 0,836 127 36 m^2 The abbreviations sq in, sq ft and sq yd are commonly used.
		3-3.B.d	square mile	1 square mile ≈ 2,589 988 km^2 1 US Survey square mile ≈ 2,589 998 km^2 1 square mile = 640 acres
		3-3.B.e	acre	1 acre := 4 840 yd^2 ≈ 4 046,856 m^2 1 US Survey acre ≈ 4 046,873 m^2

(*continued*)

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Conversion factors and remarks
3-4	volume	3-4.B.a	cubic inch: in^3	$1\ in^3 = 16{,}387\ 064\ cm^3$
		3-4.B.b	cubic foot: ft^3	$1\ ft^3 \approx 28{,}316\ 85\ dm^3$
		3-4.B.c	cubic yard: yd^3	$1\ yd^3 \approx 0{,}764\ 554\ 9\ m^3$ The abbreviations cu in, cu ft and cu yd are commonly used.
		3-4.B.d	gallon (UK): gal (UK)	1 gal (UK) $:= 277{,}420\ in^3 \approx 4{,}546\ 099\ dm^3 \approx$ 1,200 95 gal (US)
		3-4.B.e	pint (UK): pt (UK)	1 pt (UK) $:=$ (1/8) gal (UK) $\approx 0{,}568\ 261\ 25\ dm^3 \approx$ 1,200 95 liq pt (US)
		3-4.B.f	fluid ounce (UK): fl oz (UK)	1 fl oz (UK) $=$ (1/160) gal (UK) $\approx 28{,}413\ 06\ cm^3 \approx$ 0,960 760 fl oz (US)
		3-4.B.g	bushel (UK)	1 bushel (UK) $:=$ 8 gal (UK) $\approx 36{,}368\ 72\ dm^3 \approx$ 1,032 06 bu (US)
		3-4.B.h	gallon (US): gal (US)	1 gal (US) $:= 231\ in^3 \approx 3{,}785\ 412\ dm^3 \approx$ 0,832 674 gal (UK)
		3-4.B.i	liquid pint (US): liq pt (US)	1 liq pt (US) $=$ (1/8) gal (US) $\approx 0{,}473\ 176\ 5\ dm^3 \approx$ 0,832 674 pt (UK)
		3-4.B.j	fluid ounce (US): fl oz (US)	1 fl oz (US) $=$ (1/128) gal (US) $\approx 29{,}573\ 53\ cm^3 \approx$ 1,040 84 fl oz (UK)
		3-4.B.k	barrel (US) for petroleum: bbl (US)	1 bbl (US) $:=$ 42 gal (US) $= 9\ 702\ in^3 \approx$ $158{,}987\ 3\ dm^3 \approx$ 34,972 3 gal (UK)
		3-4.B.l	bushel (US): bu (US)	1 bu (US) $\approx 2\ 150{,}42\ in^3 \approx 35{,}239\ 07\ dm^3 \approx$ 0,968 939 bushel (UK)
		3-4.B.m	dry pint (US): dry pt (US)	1 dry pt (US) $=$ (1/64) bu (US) $\approx 0{,}550\ 610\ 5\ dm^3 \approx$ 0,968 939 pt (UK)
		3-4.B.n	dry barrel (US): bbl (US)	1 bbl (US) (dry) $:= 7\ 056\ in^3 \approx 115{,}627\ 1\ dm^3$
3-8	velocity, speed	3-8.B.a	foot per second: ft/s	1 ft/s $=$ 0,304 8 m/s
		3-8.B.b	mile per hour: mi/h	1 mi/h $=$ 0,447 04 m/s
3-9	acceleration	3-9.B.a	foot per second squared: ft/s^2	$1\ ft/s^2 = 0{,}304\ 8\ m/s^2$

(*concluded*)

Annex C
(informative)

Other non-SI units given for information, especially regarding the conversion factors

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Conversion factors and remarks
3-1	length	3-1.C.a	light year: (l.y.)[a]	One light year is the distance travelled in one year by light in vacuum. 1 l.y. $\approx$ 9,460 730 $\times$ 10^{15} m
		3-1.C.b	astronomical unit: ua	One astronomical unit is the mean distance of the Earth from the Sun. 1 ua $\approx$ 1,495 978 706 91(30) $\times$ 10^{11} m
		3-1.C.c	parsec: pc	One parsec is the distance at which 1 ua subtends an angle of 1″ (second of arc). 1 pc $\approx$ 206 264,8 ua $\approx$ 30,856 78 $\times$ 10^{15} m
3-7	duration, time	3-7.C.a	year: a	$\mathrm{a} := \begin{cases} 365\ \mathrm{d} \\ 366\ \mathrm{d} \end{cases}$ One tropical year is the duration between two successive passages of the Sun through the mean vernal equinox. This duration is related to the corresponding difference in mean longitude of the Sun, which depends on time in a not exactly linear form; i.e. the tropical year is not constant but decreases at a rate of nearly 0,53 s per century. The tropical year is approximately equal to 365,242 20 d $\approx$ 31 556 926 s.

[a] "l.y." is an abbreviation for the name light year.

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